

Search for $Z' \rightarrow \tau\tau$ decay with the CMS detector at LHC in pp collisions at $\sqrt{s} = 7$ TeV

F. ROMEO on behalf of the CMS COLLABORATION

Università di Perugia and INFN, Sezione di Perugia - Perugia, Italy

ricevuto il 31 Agosto 2012

Summary. — A search for high-mass resonances decaying into tau pairs is performed using a data sample of pp collisions at $\sqrt{s} = 7$ TeV corresponding to an integrated luminosity of 5 fb^{-1} collected with the CMS detector at the LHC. The number of observed events is in good agreement with the standard model prediction. An upper limit on the resonance production cross section times branching fraction is calculated to be 1363 GeV and 1096 GeV for Z'_{SSM} (Sequential Standard Model) and Z'_ψ (E_6 model), respectively, at 95% confidence level.

PACS 14.70.Pw – Other gauge bosons.

1. – Introduction

Different experimental evidences have promoted the Standard Model (SM) to the role of reference theory for high-energy particle physics. Despite its successes, there are solid indications, both from theory and experiments, that it is a low-energy remnant of some more fundamental theory involving new physical scales.

Many models beyond the SM have been proposed in the last years trying to solve some of these limits. Of particular interest are models, such as Sequential Standard Model or E_6 model [1], that include an extra neutral gauge boson— Z' —which decays to pairs of high- p_T SM particles.

Although most models with extra gauge bosons obey the universality of the couplings, some (*e.g.* Top-color or Non-universal extended technicolor models [2]) include generational dependent couplings resulting in Z' that preferentially decays to taus. This strongly supports a $Z' \rightarrow \tau\tau$ search, even if Z' decaying into other particles is discovered first.

Such a study has been performed using a data sample corresponding to an integrated luminosity of 5 fb^{-1} collected by the CMS detector in 2011. A detailed description of the search can be found in [3].

The analysis uses a cut and count strategy performed over four possible final states: $e\mu$, $\mu\tau_h$, $e\tau_h$, $\tau_h\tau_h$ (where τ_h indicates a hadronic tau decay), while ee and $\mu\mu$ have not been considered, due to a much more copious Drell-Yan background.

2. – Signal reconstruction and background estimation

The measurement makes use of three main objects— e [4], μ [5], τ [6]—reconstructed by CMS detector, which is described in detail elsewhere [7].

At trigger level, events have to have at least two of the three previous objects depending on the tau decay channel. Tau pair candidates are required to be oppositely charged, separated in $\Delta R = \sqrt{\delta\phi^2 + \delta\eta^2}$ space ($\Delta R > 0.7$) and almost back-to-back ($\cos\Delta\phi < -0.95$). A p_T cut greater than 35 GeV/ c for each $\tau_h\tau_h$ candidate and greater than 20 GeV/ c for candidates in other final states is applied, while all particles are in $|\eta| < 2.1$.

All candidates have to be isolated, where the isolation is defined with respect to energy deposit of particles in a cone centered around the lepton track. This request is the strongest discriminator between real tau candidates and misidentified QCD jets. QCD contributions can be further suppressed by requiring \cancel{E}_T (the negative vector sum of the transverse momentum of all PF objects in the event) to be greater than 20 GeV/ c for $\tau_e\tau_\mu$ and 30 GeV/ c for the other final states.

Contamination from W^\pm bosons can be reduced asking for events consistent with the signature of a particle decaying into two tau leptons by defining a unit vector along the bisector of the visible tau decay products ($\hat{\zeta}$) and two projection variables, $p_\zeta = p_\zeta^{vis} + \cancel{E}_T \cdot \hat{\zeta}$ and $p_\zeta^{vis} = \vec{p}_{\tau_1}^{vis} \cdot \hat{\zeta} + \vec{p}_{\tau_2}^{vis} \cdot \hat{\zeta}$ such that $p_\zeta - 1.25 \cdot p_\zeta^{vis} > -10$ GeV/ c for $\tau_e\tau_\mu$ and $p_\zeta - 0.875 \cdot p_\zeta^{vis} > -7$ GeV/ c for the other final states.

Any remaining contribution from $t\bar{t}$ is minimized by selecting events with no b -tagged jets. A jet is tagged as a b -jet if it has at least two tracks within the jet with the significance of the impact parameter greater than 3.3 [8].

Because of the presence of multiple neutrinos in the final state which escape CMS undetected, the visible mass (M_{vis}) is used to discriminate between signal and background.

M_{vis} is defined as $M_{vis}(\tau_1, \tau_2, \cancel{E}_T) = \sqrt{(E_{\tau_1} + E_{\tau_2} + \cancel{E}_T)^2 - (\vec{p}_{\tau_1} + \vec{p}_{\tau_2} + \vec{\cancel{E}}_T)^2}$.

To estimate the background contributions in the signal region, data-driven techniques are employed wherever possible. Slight modifications to the standard selection requirements are done to select samples dominated by the background sources (control regions). Using these enhanced background samples, selection efficiencies are measured and an extrapolation is done to the signal region for estimating the background contribution.

For example, an enhanced sample of $W + \text{Jets}$ is obtained by removing the $\Delta\phi(\tau_1\tau_2)$ and the ζ requirements from the standard selections and requiring that the transverse mass $M_T = \sqrt{2p_T^l \cancel{E}_T (1 - \cos\Delta\phi)}$ is between 50 and 100 GeV/ c^2 . This is the first control region (CR1). A second control region (CR2) can be defined by reversing the cuts on $\Delta\phi(\tau_1\tau_2)$ and ζ . Finally, the number of $W + \text{Jets}$ events in the signal region is estimated as $N_{Signal}^{W+jets} = N_{CR1}^{W+jets} \cdot \epsilon_{CR1}^{\cos(\Delta\phi), p_\zeta} \cdot (\epsilon_{CR2}^{50 < M_T < 100})^{-1}$, where $\epsilon_{CR1}^{\cos(\Delta\phi), p_\zeta}$ and $\epsilon_{CR2}^{50 < M_T < 100}$ are the efficiencies for the corresponding cuts.

Similar approaches are used for the other main backgrounds ($t\bar{t}$, QCD), while data-to-MC scale factors correcting the expected contributions from the simulated samples are used for backgrounds from Drell-Yan and diboson production.

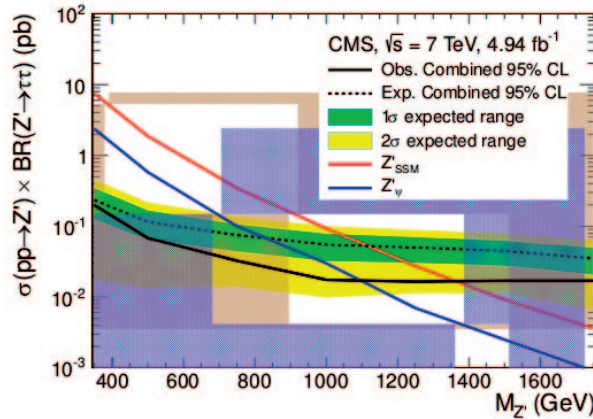
TABLE I. – Number of observed data events and estimated background events. The first and second uncertainties are the statistical and systematic, respectively.

Sample	$\tau_\mu\tau_h$	$\tau_e\tau_h$	$\tau_e\tau_\mu$	$\tau_h\tau_h$
$Z \rightarrow \tau^+\tau^-$	$804 \pm 53 \pm 44$	$462 \pm 56 \pm 24$	$816 \pm 58 \pm 44$	$30.9 \pm 3.6 \pm 4.3$
$Z \rightarrow \mu^+\mu^-$	$20.8 \pm 8.3 \pm 1.1$	–	–	–
$Z \rightarrow e^+e^-$	–	$220 \pm 24 \pm 11$	–	$0.66 \pm 0.33 \pm 0.22$
W + Jets	$459 \pm 26 \pm 29$	$181 \pm 36 \pm 13$	$83 \pm 15 \pm 7$	$5.8 \pm 1.7 \pm 1.1$
WW	$24.6 \pm 0.8 \pm 0.8$	–	$55.6 \pm 1.4 \pm 1.9$	–
WZ	–	–	$5.6 \pm 0.35 \pm 0.22$	–
$t\bar{t}$	$46.2 \pm 6.9 \pm 3.7$	$10.8 \pm 2.8 \pm 0.9$	$9.6 \pm 1.2 \pm 0.7$	$0.00^{+0.76+0.15}_{-0.00}$
QCD	$72 \pm 18 \pm 8$	$185 \pm 31 \pm 19$	$45.1 \pm 3.3 \pm 9.0$	$467 \pm 26 \pm 67$
Total	$1427 \pm 63 \pm 53$	$1058 \pm 77 \pm 35$	$1015 \pm 60 \pm 45$	$504 \pm 26 \pm 67$
Observed	1422	1043	1044	488

3. – Results

Background contributions are reported in table I, where the errors are statistical and systematic, respectively. The main source of systematic uncertainty is due to the limited statistics of the control regions used to estimate backgrounds. Other sources taken into account are due to: lepton identification, tau and jet energy scale, luminosity, parton distribution functions, initial and final state radiation.

Since no evidence of excess of events for $Z' \rightarrow \tau\tau$ production is observed, an upper limit at 95% CL on $\sigma(pp \rightarrow Z') \times BR(Z' \rightarrow \tau\tau)$ as a function of M'_Z for each final state is calculated. The final combined limit, obtained using a joint likelihood, is reported in fig. 1. The limits are evaluated to be 1363 GeV and 1096 GeV for Z'_{SSM} (Sequential Standard Model) and Z'_ψ (E_6 model), respectively.

Fig. 1. – Combined 95% CL upper limits on $\sigma(pp \rightarrow Z') \times BR(Z' \rightarrow \tau\tau)$ as a function of M'_Z .

REFERENCES

- [1] LEIKE A., *Phys. Rep.*, **317** (1999) 143.
- [2] LANGACKER P., *Rev. Mod. Phys.*, **81** (2009) 1199, doi:10.1103/RevModPhys81.1199.
- [3] CMS COLLABORATION, <http://arxiv.org/abs/1206.1725> (2012).
- [4] CMS COLLABORATION, Physics Analysis Summary EGM-10 - 004 (2010).
- [5] CMS COLLABORATION, CMS Physics Analysis Summary MUO-10-002 (2010).
- [6] CMS COLLABORATION, CMS Physics Analysis Summary CMS-PAS-TAU-11-001 (2011).
- [7] CMS COLLABORATION, *JINST*, **03** (2008) S08004.
- [8] CMS COLLABORATION, CMS PAS BTV-10-001 (2010).